XIV. *Of the Organs of the Human Voice.* *By Sir* CHARLES BELL, *K.G.H. F.R.S. L. & E. &c. &c. &c.*

Read February 2, 1832.

THE organs of the Human Voice are related to many interesting inquiries in science and philology; and yet it is remarkable that this subject has hitherto occupied no place in the Transactions of the Society. In a matter so open to observation as the anatomy of the throat, there can, indeed, be no new parts discovered; but it will be easy to show that their actions have been very negligently treated.

It will not, I hope, lessen the interest of the inquiry, that I acknowledge having an ulterior object in it. The nerves distributed to the neck and throat are the most intricate of all. That they have not been unravelled, and distinct uses assigned to each, is owing to the complexity and the numerous associations of the organs to which they tend. When we shall have seen the necessity of combination among the various parts, for producing the simplest effort of the voice, we shall find a reason for these numerous nerves, and for their seeming irregularities.

In reviewing the writings of physiologists we observe defects which are obviously to be ascribed to the great complexity in the organization, and the real difficulty of the subject: but there are others which arise from the habit of resting contented with assigning one use for a part in the animal frame; whereas there is nothing which should more excite our admiration, than the variety of offices destined to be performed by the same organ. It is in contemplating the extent of combination established among the parts of the human body, that we become sensible of its perfection above all comparison with things artificial; and this is especially true with regard to the organs of the voice. They are remarkable for their union or cooperation in function; they all perform more than one office, and are interwoven and associated

with parts which serve a double or even a treble function. But we ought not to be surprised at the intricacy of structure in the human organs of voice, when we find them capable of imitating every sound of bird or beast, excelling all instruments of music in clearness and expression, and capable of making those infinite changes on articulate sounds, which form the languages of the different nations of the earth.

Although there be one subject,—Articulate language,—on which I shall principally comment, as being that in which the treatises on the voice are altogether defective; yet, as there are lesser points in which I think authors are in fault, I shall take the subjects consecutively or systematically. I do this in the hope of affording, at the same time, a sounder foundation in anatomy, to those members of the Society who are more capable of pursuing this part of philosophy in all its curious and elegant subdivisions.

It will be convenient to divide the inquiry into three heads:—the *Trachea*, the *Larynx*, and the *Pharynx*.

Under the head of *Trachea*, and through the whole investigation, it is necessary to keep the different functions of the part in mind; or we shall be appropriating to the voice, structures which have reference to other functions. We read that the trachea is formed of imperfect hoops of cartilages, joined by membranes, and that it is flat on the back part, for these reasons: that it may be a rigid and free tube for respiring the air—that it may accommodate itself to the motions of the head and neck—and that it may yield, in the act of swallowing, to the distended œsophagus, and permit the morsel to descend. This is perfectly correct; but there is a grand omission. Whilst all admit that a copious secretion is poured into this passage, it is not shown how the mucus is thrown off.

There is a fine and very regular layer of muscular fibres on the back part of the trachea, exterior to the mucous coat, and which runs from the extremities of the cartilages of one side to those of the other *. This transverse muscle is beautifully distinct in the horse. When a portion of the trachea is taken out, and everything is dissected off but this muscle, the cartilages are preserved in their natural state; but the moment that the muscular fibres

* See Plate X. fig. 3. A.

are cut across, the cartilages fly open. This muscle, then, is opposed to the elasticity of the cartilages of the trachea. By its action it diminishes the calibre of the tube, and by its relaxation the canal widens without the operation of an opponent muscle.

The whole extent of the air-passages opens or expands during inspiration; and then the trachea is also more free; but in expiration, and especially in forcible expectoration and coughing, the trachea is diminished in width. The effect of this simple expedient is to free the passage of the accumulated secretion; which, without this, would be drawn in and gravitate towards the lungs. When the air is inspired, the trachea is wide, and the mucus is not urged downwards; when the air is expelled, the transverse muscle is in action, the calibre of the tube is diminished, the mucus occupies a larger proportion of the canal, the air is sent forth with a greater impetus than that with which it was inhaled, and the consequence is a gradual tendency of the sputa towards the top of the trachea. In the larynx, the same principle holds; for as the opening of the glottis enlarges in inspiration, and is straitened in expiration, the sensible glottis, by inducing coughing, gets rid of its incumbrance. Without this change of the calibre of the trachea, the secretions could not reach the upper end of the passage, but would fall back upon the lungs.

Experiments have been formerly made*, which, although no such view as I now present was in contemplation, prove how the action of the transverse muscle tends to expel foreign bodies. The trachea of a large dog being opened, it was attempted to thrust different substances into it during inspiration; but these were always sent out with impetus, and could not be retained. Why the dog could not be thus suffocated is apparent; the tube is furnished with this most salutary provision to secure the ready expulsion of all bodies accidentally inhaled; the air passes inwards, by the side of the foreign body; but in its passage outwards, the circumstances are changed by the diminished calibre of the canal, and the body, like a pellet filling up a tube, must be expelled by the breath.

Looking on the form and muscular structure of the trachea in man, as providing for expectoration of the secretions poured into the tube, what shall we think of the tracheæ of birds, which are formed by cartilages of complete

* By M. Favier.

circles, and which have no compressing muscles? Does it explain the peculiarity, that all the air-tubes of birds are dry; that their lungs are motionless; and that in the air respired by them there is no moisture?

These are the reasons why I must reject the opinion of PORTAL, that the transverse muscle of the trachea is to give force to the breath in speaking.

The trachea, and all that portion of the windpipe which extends from the larynx to the lungs, may be considered as the porte-vent, or tube which conveys the air from the bellows to the reed of the organ-pipe; and it has even less influence on the quality of sound than the porte-vent. If this portion of the air-tube were to vibrate and give out sound, it would interfere with, and confuse those which proceed from the glottis. The imperfect circle formed by the cartilages of the trachea, and their isolation from each other, are ill suited to convey sound.—But I am now to notice a more particular provision against the propagation of sound downwards by this passage.

If on inspecting a musical instrument we should find a spongy body of the consistence of firm flesh in contact with a cord or tube, and an apparatus by which this body might be pressed against the vibrating part, we would not hesitate to conclude that it damped or limited the vibration. The THYROID GLAND is a vascular, but firm substance, which, like a cushion, lies across the upper part of the trachea*. Four flat muscles, like ribbons, arise from the sternum, first rib, and clavicle, and run up to the thyroid cartilage and os hyoides, over the surface of this glandular body. These muscles are capable of bracing it to the trachea. If it be admitted that the vibration of the trachea would only produce a continued drone, rising over the inflections of the voice and adding nothing to its distinctness, we may perceive in the adjustment of the thyroid gland to the trachea the most suitable means of suffocating or stopping the vibrations from descending along the sides of the tube.

Comparative anatomy is often a test of the correctness of our inferences drawn from the human body. I reflected that if I were right in my idea of this being one of the uses of the thyroid gland, there should be no such body, so placed, in birds: and that, following up the inquiry, if we were not likely to discover the function of that gland, we might nevertheless learn why it is so singularly placed. In birds the sounding apparatus is at the lower part of the

* See Plate X. fig. 1. D. D.

trachea; the larynx being, in a manner, divided in its office. At the upper opening there is the structure, and action, and sensibility, constituting it a guard against foreign matter; but the proper organ of sound is formed on the lower extremity of the trachea and in the chest. Hence, in birds, there is this remarkable difference, that the sound must ascend along the trachea. Directed by this consideration, it is not without interest that we notice the absence of the thyroid gland in them; that the trachea itself is a firm tube with cartilages of entire circles; and that there is nothing to suffocate the rising vibrations. In no animal is the thyroid gland of the same relative magnitude as in man.

But it is easy to prove that the trachea has no influence upon the voice. Both in the open pipe or flute, and the pipe stopped at the bottom, as the syrinx, the length determines the note,—lengthening the tube depresses the note, and shortening it makes the sound more acute. A similar effect should result from the elongation and shortening of the trachea, if the changes of the voice depended upon it: but, on the contrary, the trachea is lengthened during the high note, while it is shortened as the voice descends, and the notes become graver*. I have no ear to determine what harmonic sounds attend the human voice; but supposing that sounds proceed from the trachea, which is shortening, at the same time that they proceed from the upper part of the tube, which is lengthening, it is clear to demonstration that the two portions of the tube can never consent or keep any proportion in their vibrations.

For these reasons I apprehend that in the structure and condition of the trachea, the design manifestly is to suffocate the vibrations of sound, and so to impede the motions originating in the larynx from being propagated downwards.

Pursuing our inquiry into the organs of the voice independently of articulation, and looking more particularly to the *Larynx*, we shall find that the common opinion is confirmed by experiment and every analogy, that the glottis is the primary seat of sound—the source of the vibrations communicated to the air as it is breathed. But to consider the motions of the glottis, and even the modulations of the air in the larynx, as the sole source of sound, would be

* Fabricius ab Aquapendente, seeing the contraction and elongation of the trachea during the changes of the voice, presumed that these motions must be the cause of them. Dodart showed the incorrectness of this.

incorrect. FERREIN described the edge of the glottis as being like the strings of the violin, and the air brushing over it like the bow. But even in that supposition, though the vibration of the string of the violin is necessary to the production of sound, yet that sound receives modification through the form and condition of the instrument. As the same chord, vibrating in the same time, will produce a sound the quality of which varies in different instruments, so will the sound of the chordæ vocales be influenced in the pharynx. As a tuning-fork, or a moveable musical instrument, will have the quality and power of the tone changed by its position and the material with which it is in contact, so will the vibrations of the human glottis be affected by the parts above and against which the sound is directed.

The breath, which plays inaudibly in respiration, becomes vocalized when the ligaments of the glottis, or chordæ vocales, are braced so as to cause the edges of the glottis to vibrate in the stream of air. In a wind instrument the air must be impelled with a force to make the sides of the tube vibrate; so, in the production of sound from the human organs, there must be a certain pressure of the column of air. But in the organs of the voice there is this superiority, that there are not only the means of regulating the pressure of the column of air, but of adjusting the vocal chords, so as to suit them to the most delicate issue of the breath. The metal tongue in the organ-pipe is, by lengthening or shortening it, accommodated so as to vibrate in time with the air contained in the tube. So is the edge of the glottis regulated; but with an apparatus for adjustment the most perfect.

Besides the adjustment of the vocal chords, there is a very superior provision in the motions of the chest which supply the air, to that of any musical instrument. Although the organ has allotted to each note a separate pipe, whose relative dimensions are proportioned with mathematical precision, yet the air propelled through the pipes can never be so regulated as it is by the combination which exists betwixt the motions of the chest and the glottis. The church organ could not be made to approach the precision of adjustment in the human organs, were there as many pairs of bellows as there are pipes, and each adjusted by a weight or spring, to accommodate the pressure of air to the dimensions of the pipes *.

Referring to the Plates for the anatomy†, I may continue my comment on

* Which is attempted in some automata.

† See Plate IX.; and Plate X. fig. 2.

the form and uses of the parts. The thyro-arytenoid ligaments, or chordæ vocales of FERREIN, are the lower ligaments of the glottis; they form the chink of the true glottis. These ligaments do not stand distinct from the sides of the tube, but the fine lining membrane is reflected over them. This membrane, sinking between the inferior and superior ligaments, forms there the sacculus or ventriculus laryngis. Another reflexion passes from the extreme point of the appendix of the arytenoid cartilage to the base of the epiglottis. These inflexions of the membrane of the glottis produce a considerable intricacy in the passage of the larynx. Nevertheless, when this piece of anatomy is fully displayed, the number of muscles inserted into the arytenoid cartilages, and the effect of their motions on the lower ligaments, point to these as the chief parts, and to the others as subordinate, in producing sound.

There are, however, circumstances which lead to the belief that the sacculus or lateral cavity of the larynx has much influence on sound. We perceive that one effect of this cavity is to hold off the inferior ligament from the side of the tube, and to give freedom to its vibrations. But the varieties in its size and form, exhibited by comparative anatomy, and the influence which some of the muscles of the arytenoid cartilages* must have upon it, point it out as an essential part of the organ of sound; and the ear-piercing cries which belong to such animals as the Beelzebub ape, in which this cell is large, confirm the notion.

The seat of the vibrations which produce the voice is so fairly indicated by the whole anatomy, and confirmed by observation, that there is hardly an excuse for those experiments which have exhibited the motions of the chink of the glottis in living animals†. It is, on the whole, better to wait our opportunity of inspecting these parts in action in man. In consequence of wounds of the throat, I have had repeated occasions to witness the motions of the glottis in man, both during simple breathing and in speaking. On every inspiration the glottis is dilated. Upon asking the patient to speak, and encou-

* Thyro-arytenoideus and Crico-arytenoideus.

† The larynx of a dog being partially dissected, so as to expose the glottis, the experimenter tortured the animal to observe how the acuteness of the note, and the constriction of the chink of the glottis bore relation to the severity of pain. After ascertaining the degree of contraction from the pinch of the tail to the application of the red-hot iron, he set himself with a tuning-pipe to sound in harmony.—Archives Générales de Medecine, tom. xxv. Mars 1831.

raging him, when no sound proceeded, by saying that I could understand him by the motion of his lips, I have seen that in the attempt at utterance, the glottis moved as well as the lips. Although these occasions be too painful to admit of protracted experiment, I could not omit observing that there is a motion of the glottis in correspondence with the efforts of the other organs of voice.

We have already understood the necessity of the tongue of the organ-pipe being adjusted in its length, both to the force of the wind from the bellows, and that it may vibrate in correspondence with the column of air in the tube. Granting that the analogy between this instrument and the organ of the voice is just, we must acknowledge the very superior means possessed by the living parts, of drawing out the margin of the glottis, to that by which the tongue of the organ-pipe is adjusted.

If we should adopt the fancy to compare the membrane which is stretched over the ligament to a drum, then the arytenoid muscles would be the braces to tighten the membrane, and the ligaments would be as the snares on the reverse of the drum. But all such comparisons serve to show that, taking this portion only of the apparatus for the voice, it surpasses every instrument in the property of accommodation—of sounding in unison with the rest of the tube, and with the column of air.

Of the Pharynx, and of the formation of articulate Sounds.

We come now to a division of our subject, which, notwithstanding its higher interest, has been imperfectly treated by authors, and where the actions essential to articulate language have been altogether omitted.

Tracing the volume of simple sound in its ascent from the glottis, we see how well the epiglottis is calculated to direct it on the passages above*. Immediately over the epiglottis hangs the velum palati; this curtain is formed by certain muscular fibres, which draw down the mucous membrane from the back part of the bony palate into a great fold; whilst other muscles, their opponents, furl it up. This velum forms a partition which divides the mouth from the posterior cavity, arrière-bouche, or pharynx; and the velum, uvula, and arches of the palate vary their condition during the production of simple sounds.

* See Plate IX.

When the parts are displayed, so that we may look on the outside and posterior aspect of the great bag of the pharynx, we see how well it is adapted for the office which I shall assign to it in the formation of the human voice. It presents to our view a flat expanded web, of a fleshy or muscular texture, and it extends from the base of the skull to the extremities of the horns of the os hyoides and those of the thyroid cartilage, between which it is stretched and held out. Behind, its connexions are loose; and as it forms a principal boundary of the bag of the pharynx, the great cavity of that bag is directly in front of it. If we trace the pharynx upwards from the closed extremity of the œsophagus, we perceive the glottis opening into it below; whilst above, it is terminated by the posterior nostrils, and anteriorly by the mouth.

Considering the passage for the voice as one irregular cavity, extending from the glottis to the lips and nostrils, we shall find it subject to great changes, and powerful in its influence on the voice. For although the breath is vocalized by the larynx, both the musical notes in singing and the vowels in speech, are affected by the form and dimensions of this cavity.

Notwithstanding the ingenuity displayed in experiments on animals, to show that their cries proceed from the larynx, we have no authority to disregard the fact, that when a person who has divided the pharynx, and exposed the top of the windpipe, attempts to speak, no sound issues from the larynx. By great effort he may produce a noise; but anything like the common effort of speaking is attended with no audible sounds. From this we must infer that the delicate vibrations, necessary to articulate language, are influenced not merely by the action in the glottis, but by the condition of the walls of the pharynx; the cavity into which the sound is thrown.

In this part of the air-passage, we shall find an exact correspondence with the flute or pipe, in as far as it is lengthened during the grave sounds, and shortened in the acute. Even if it were proved that the note is made to rise and fall by the contractions of the glottis, the great apparatus employed to move the pharynx cannot be useless. We are countenanced in concluding, that as the tube of the organ is adjusted to the reed, so is the condition of the pharynx made to correspond with these contractions of the glottis. It is impossible to see a singer running up the notes to the highest, without admitting that there must be a powerful influence produced through the alternate short-

ening and elongation of the pharynx and mouth. To allow the cavity to be shortened in the greatest degree, the larynx is raised, and the lips retracted; on the contrary, the trachea descends, and the lips are protruded, to lengthen the cavities, and to give out the lower or graver notes.

Of Articulation.

In pronouncing the simple continued sounds, the vowels, and the diphthongs, which are the combinations of open sounds, the pharynx, at all times irregular, varies its form or dimensions, without interrupting or cutting the sounds. These sounds are universal and expressive. What we have now to consider are more conventional, and form the constituents of articulate language.

It has been imagined that the vocalized breath ascending into the mouth is there divided, and articulated by the tongue, teeth and lips; and that this comprehends the whole act of speech. Such a description implies a very imperfect acquaintance with the actions which produce articulate language.

It is now my purpose to show, that in articulating, or forming the consonants, the pharynx is a very principal agent; and that this smaller cavity is substituted for the larger cavity of the chest, to the great relief of the speaker, and the incalculable saving of muscular exertion.

The late Dr. Young made a comparison of the power employed by a glass-blower, in propelling the air through his tube by the force of his cheeks, and in propelling it by the force of his lungs; and calculating the ease with which the lesser cavity is compressed in comparison with the greater,—that is, the cavity of the mouth compressed by the muscles of the cheeks, compared with the whole extent of the chest compressed by the muscles of respiration,—he concluded, that the weight of four pounds would produce an operation through the lesser cavity, equal to seventy pounds weighing on the larger cavity.

The quality of fluids, by which they transmit pressure equally in all directions, is the cause of this and of some other results which appear paradoxical. It is a property too nearly allied to mechanical power, and too important to be left out of the scheme of animal structure.

When a forcing-pump is let into a reservoir, it produces surprising effects. The piston of the hydraulic press being loaded with a weight of one pound, the

same degree of pressure will be transmitted to every part of the surface of the reservoir, equal in magnitude to the base of the piston. And on the contrary, supposing the power to be employed on the reservoir for the purpose of raising the piston, it would require the weight of a pound on every portion of the superficies of the reservoir, equal in extent to the base of the piston, to raise the piston with a force of one pound.

We cannot fail to notice the effect of this law on the cavities of the animal body, in diminishing the power of muscular bags in proportion to their increased capacity.

Elastic fluids are subject to a similar influence, from the pressure extending in every direction, and the resistance always being equal to the pressure. A man standing on the hydraulic bellows, raises himself by blowing into the tube; and contrariwise, the weight of his body does not produce from that tube a blast of air superior to the force of contraction of his cheeks. A very slight pressure against the nozzle of the common bellows will resist the compression by the handles; and by blowing into the nozzle, we may raise a great weight placed on the boards. To reconcile us to the influence of this principle, as applicable to the animal economy, we shall take an example before applying it to our present subject.

A sailor leaning his breast over a yard-arm, and exerting every muscle on the rigging, gives a direction to the whole muscular system, and applies the muscles of respiration to the motions of the trunk and arms, through the influence of a small muscle that is not capable of raising a thousandth part of the weight of his body. He raises himself by the powerful combination of the muscles of the abdomen, chest and arms; but these muscles are controuled and directed by the action of a muscle which does not weigh five grains. The explanation is this;—a man preparing for exertion, draws his breath and expands his chest. But how is this dilatation to be maintained? if the muscles which expand the chest are to continue in exertion to preserve it so, there must be a great expenditure of vital force; besides, these muscles are now wanted for another office. The small muscle that closes the chink of the glottis suffices. It contracts on the extremity of the windpipe; and here, acting so as to confine the column of air, it is superior to the united power of all the muscles of the chest and trunk of the body which act upon the cavity of the

thorax. However powerful the muscles of expiration may be in compressing the chest, their influence is very small on the column of air in the windpipe; the pressure there being no more than on any part of the walls of the chest, which is of the same diameter as the base of the tube. The closing of the glottis by this small muscle, throws all those of the chest and abdomen, which are otherwise muscles of respiration, free to act as muscles of the trunk and arms.

But if any defect of the windpipe, or of the muscle which closes it, permit the air to escape, the muscles of the chest and abdomen sink with the falling of the chest; they become muscles of expiration, and lose their power as muscles of volition, consequently all powerful efforts cease in the instant. When an unhappy suicide thinks to perpetrate self-destruction by dividing his windpipe, his sensations of sudden and total failure of strength announce the accomplishment of the act; but he is deceived. In the moment of lunatic excitement, his energies are wound up, and his breath is drawn and confined; but now the trachea being divided, in the instant he is seized with feebleness; for the compressed air is let loose, the chest subsides, and the whole muscles of the trunk and arms are lost to the actions of volition. He feels as if struck with the sudden influence of death; his actual death depends on other circumstances.

Thus we perceive that the muscle of the glottis, not weighing a thousandth part of the muscles of the trunk of the body, controuls them all; changing them from muscles of respiration to muscles of volition; and this it is enabled to do on the principle of the hydraulic press.

We are by these instances prepared to understand the great importance in the animal economy, of power being employed on the lesser cavity in preference to the larger*; and how much will be saved if the appulse necessary in articulation be given by the pharynx instead of by the greater cavity of the thorax.

* The principle is as important in its application to pathology as to the natural functions. It explains the weak pulse which attends the dilated heart; how the contractions of the uterus become more powerful in the progress of labour; and why the distended bladder acts with diminished power in the expulsion of the urine through the urethra. On the same grounds we understand how a slight spasm in the canal of the urethra will resist the most powerful contractions of an enlarged and thickened bladder, aided by the pressure of the abdominal muscles.

In a person whom I had the pain of attending for a long time after the bones of the upper part of the face were lost, and in whom I could look down behind the palate, I saw the operation of the velum palati. During speech it was in continual motion; and when this person pronounced the explosive letters, the velum rose convex, so as to interrupt the ascent of the breath in that direction; and as the lips parted, or the tongue separated from the teeth or palate, the velum recoiled forcibly.

These facts lead us to the further contemplation of the pharynx. We see it to be a large cavity behind the palate, formed by a dilatable bag, and acted on by many muscles. We have seen that the volume of sound issues into it from the glottis below; and that although it opens into the nose above, yet this passage is closed, whenever the velum is raised, like a valve, in the manner just described; at such a time, if the mouth be also shut, the bag will be closed on all sides, and may then suffer distention by the vocalized breath ascending through the glottis.

In speaking, much of the sound, as of the vowels and diphthongs, is the uninterrupted issue of the vocalized breath, modulated by the passages, and differently directed, but not checked or interrupted. The consonants are the same sounds checked by the tongue, lips, or teeth. At the moment of this interruption, the pharynx, being distended, is prepared to give an appulse by its muscular action exactly in time with the parting lips.

If we grasp the throat whilst speaking, so that the fingers embrace the bag of the pharynx, we shall feel that each articulate sound is attended with an action of the pharynx; and preceding each explosive letter, we shall be sensible of a distention of the throat. By a close attention to the act of breathing, we shall perceive that whilst the distended chest falls gradually and uniformly, the bag of the pharynx is alternately distended and compressed in correspondence with the articulated sounds.

We can now conceive that if each appulse of the breath in speaking arose from the action of the chest, it would be attended with great and unnecessary exertion; since in proportion to the size of the reservoir and the smallness of the tube that gives issue, would be the force required on the sides of the reservoir to produce an impulse along the tube. If each consonant and accented syllable required the action of the whole thorax, we should find that a

man, instead of being able to deliver an oration of some hours in length, would be exhausted in a few sentences; like a person who bellows and gives pain by the violence and consequent ungracefulness of his action.

If we enter into a more particular examination of the formation of the consonants, we shall perceive that, without the action of the pharynx, those letters must have been mutes, which, through its operation, do in fact give the greatest force and distinctness to language. The circumstance which I have to notice could not altogether escape the observation of grammarians. They speak of the guttural sounds as belonging to the production of certain consonants. Bishop WILKINS expresses this by referring to that *murmur* in the throat before the breath is emitted in pronouncing these letters. Thus grammarians distinguish the mute letter P, which has no sound previous to the parting of the lips, from B, which has a guttural sound before the explosion of the lips.

Had the cause of this sound been investigated, these ingenious men would have presented the subject to us in greater simplicity. "This guttural sound," they say, "is produced by a compression of the larynx or windpipe:" but this has no meaning, and cannot pass for an explanation. This murmur, like all other sounds, proceeds from the vibration of the glottis; but, as we have seen, the glottis cannot vibrate without the ascent of the breath through it;—how then is this murmur to be produced when the mouth is closed, and there is no aspiration? The air ascends because the bag of the pharynx, or arrière-bouche, is filling. It is during the distention of the bag, that the breath ascends and produces the sound which precedes and gives the character to some of the explosive letters; and it is this preceding murmur which distinguishes these letters from others, produced by the same position of the "organs" in the mouth, but which are mute or nasal. Thus the triad of consonants D, B, G (hard), are called semimutes, because, without the assistance of any vowel, they are attended with a faint sound, "which continues for a little time." The letters T, P, K are produced by the same position of the organs in the mouth, but they are preceded by no murmur; and therefore it is that they are called mutes: whereas, in D, B, G, the pharynx fills, preceding the parting of the lips. It is this filling of the pharynx, and consequent murmur in the glottis, which gives reason for the grammarians to say

that these letters, D, B, G, are accompanied with a sound, though not joined to a vowel, and to call them semimutes.

Grammarians admit "that the mouth is not the proper organ for producing sound, but only the organ for modulating and articulating the specific sounds;" and having explained the formation of the vowels, they proceed to the formation of the consonants, accounting for their peculiar sounds by the position of the lips, tongue, and palate.

We perceive that their explanation must necessarily be imperfect, owing to their ignorance of the anatomy, and especially of the action, of the pharynx. For example, P, B, and M, they say, are consonants formed by the application of the lips to each other: but this leaves the peculiar character of each letter unexplained, since all three are formed by the lips. The real difference is this: P gives no sound previous to the parting of the lips; it is the vowel abruptly sounded by their separation. B differs only in as much as the sound precedes the opening of the lips in the manner I have just explained; and as the pharynx, after being distended, contracts and forces open the lips, this letter is very properly called explosive. M, too, is in part owing to the articulation through the lips; the sound, commencing in the vowel, is interrupted by the shutting of the lips; after which it continues in a murmur; with this difference from the guttural murmur,—that it ascends into the cavities of the face, the velum being lifted. The same difference is shown in other letters, as F and V. If we attempt to articulate certain letters in a whisper, we shall find how much the distinctness depends on the swelling of the pharynx. In a whisper it is with much difficulty that we can distinguish P from B, or T from D, or G (hard) from K.

Thus we see that the consonants, classed according to their formation in the mouth, have varieties consequent on the action of the pharynx. 1st, The consonants formed by the closed lips; 2nd, Those formed by the meeting of the lips and teeth; 3rd, Those formed by the tip of the tongue and palate; 4th, Those formed by the dorsum of the tongue and palate. All of these admit of variety by the operation of the pharynx and velum; viz. they are mutes, explosive semimutes, and nasal liquids. For example, taking the position of the tip of the tongue against the teeth as forming a consonant, we have T, the mute; D, the semimute, in which the sound precedes the explosion; and N, the sound

which rings through the nasal cavities after the closing of the passage through the mouth.

From the same misconception of the actions which combine to form the voice, it may be, that grammarians do not give us a very clear account of emphasis and accent. We perceive that there are two sources of the force with which the words are uttered,—the chest, and the pharynx. The emphatic delivery of several words or syllables must proceed from the forcible expulsion of the breath by the effort of expiration; but the emphasis on the single syllable, and the forcible enunciation of the letter on which the clearness and distinctness, and sometimes the meaning, of words depend, must be produced by the effort of the pharynx.

Proofs of the Correctness of the Opinions advanced, drawn from the effects of accident and of disease occurring under the Author's observation.

1. A child having drawn the broken shell of an almond into its windpipe, was in momentary danger of suffocation; and could utter no sound until the shell was extracted by incision*.

2. Owing to disease of the glottis, it was necessary to open the membrane between the thyroid and cricoid cartilages; the voice instantly ceased; and no sound could be produced, while the air passed freely from the wound: "the harsh sawing sound of the air in the contracted glottis immediately ceased, and the air played easily with a siffling sound through the wound."

3. A small pebble having fallen into the glottis of a child, there was a stridulous sound in drawing the breath, but no voice in the expulsion of the breath.

4. When an ulcer had destroyed the margins of the glottis, and the sacculi, the patient spoke in a husky whisper, "reedy and very feebly."

5. Thickening of the membrane of the glottis and epiglottis had a similar effect, the person speaking painfully in a whisper.

6. A man died of suffocation from a pustule, which formed on the margin of the false glottis; whilst he breathed, the sound was like the noise of a saw, harsh and loud.

* The probe was passed several times into the windpipe, and past the broken shell without discovering it. It had been caught by the action of the transverse muscle, and the sharp broken edge forced into the mucous membrane; which was the reason that it was not coughed out of the wound.

7. The epiglottis being destroyed, and a deep ulcer in the sacculus, "the man attempted to call, but with a husky sound."

8. When the interior of the larynx was coated with coagulable lymph, except the clangour, during coughing, the voice was quite gone.

9. When the suicide has divided the larynx from the tongue, and opened the pharynx, no sound issues from the larynx in his attempt to speak; and it requires a powerful effort to produce any sound at all. When the glottis is thus exposed, it is seen to move in the effort to speak.

10. The loss of the velum pendulum palati was attended with the defect of articulation; the sounds were run together and nasal.

11. When polypus fills the cavities of the face, the voice is deficient in sonorousness and clearness.

12. When a communication is formed between the mouth and nose, the sound is nasal, and the articulation imperfect.

13. The entire removal of the bones of the face deprived the voice of all force, and gave it a sound which we should have called nasal, had any part belonging to the nose remained.

14. The defect of nervous influence in depriving the muscles of the velum and pharynx of due tension (as in apoplexy,) produces stertor or snoring. That this depends in a great measure on the relaxation of the velum, appears from this,—that changing the position of the head, so that the velum shall not hang against the back part of the pharynx, removes the distressing sound.

15. In extreme weakness, as from wounds and loss of blood even to insensibility, groaning proceeds from the condition of the glottis; as if the call for sympathy and assistance were intended to be the last effort of life.

By these facts it appears; 1st, That the trachea gives out no sound of itself; 2nd, That when the passage of the trachea is much encroached upon, the column of air is not sufficient to move the cords of the glottis; 3rd, That whatever interferes directly with the motion of the glottis, reduces the voice to a whisper; 4th, That when the larynx is separated from the pharynx, delicate sounds are not produced; and therefore an influence of the pharynx upon the stream of air is necessary to the production of such sounds; 5th, That any permanent opening or defect of the velum, which shall prevent the distention of the pharynx and the closing of the passage to the nose, renders articu-

lation defective; 6th, That the removal of the cells of the face, equally with their obstruction, deprives the voice of its body and clearness; 7th, In nervous relaxation of the muscles of the throat, there is sound; but its nature evinces how much the proper action of the muscles is necessary to the voice.

Recapitulation.

It is curious, and not without its use, to observe how many parts must conform, and how many actions must accurately correspond, to produce the simplest sound; and how many additional combinations there must be for the formation of articulate voice.

As we may audibly breathe through a trumpet without producing a note of music, so we breathe without the tremor of the glottis to produce voice properly, but only the whisper. To vocalize the breath, there must not only be a certain strength of impulse in the column of air, but there must be an adjustment of the vocal chords in the glottis. The mere impulse of the breath, however forcible, as in sneezing, does not necessarily move the chords of the glottis.

The chordæ vocales being strung by the action of their muscles in correspondence with the forcible expulsion of the breath, they vibrate: this vibration is reverberated on the column of air; and by an adjustment of the passages above, there is a correspondence between the motions of the glottis and the vibrations of the column of air. The breath, thus vocalized, forms the several open sounds or vowels by the change or modulation of the passages: for by the more or less contraction and dilatation of the tube, these sounds are modified; the vibrating air being differently directed, and impelled against different portions of the tube.

The musical notes are in the same way produced by changes in the force with which the voice is propelled, the degree of tension in the chordæ vocales, and the modulation or change in the form of the open passages. There is nothing more surprising than the precision with which the notes of the human voice are produced, as when we hear it rising above the sound of the church organ, the notes more liquid and distinct, and descending in a solfeggio of notes and half-notes, as if each arose from a different pipe, or were struck on a distinct instrument. Yet these falls are consequent on muscular action, which

alters the diameter and form of the glottis, and the length and diameter of the pharynx. This minute accommodation of action does not merely evince the perfection of the organ, but shows a most surprising command possessed over it: and in this respect the muscular apparatus of the throat does not yield in comparison with that of the eye itself.

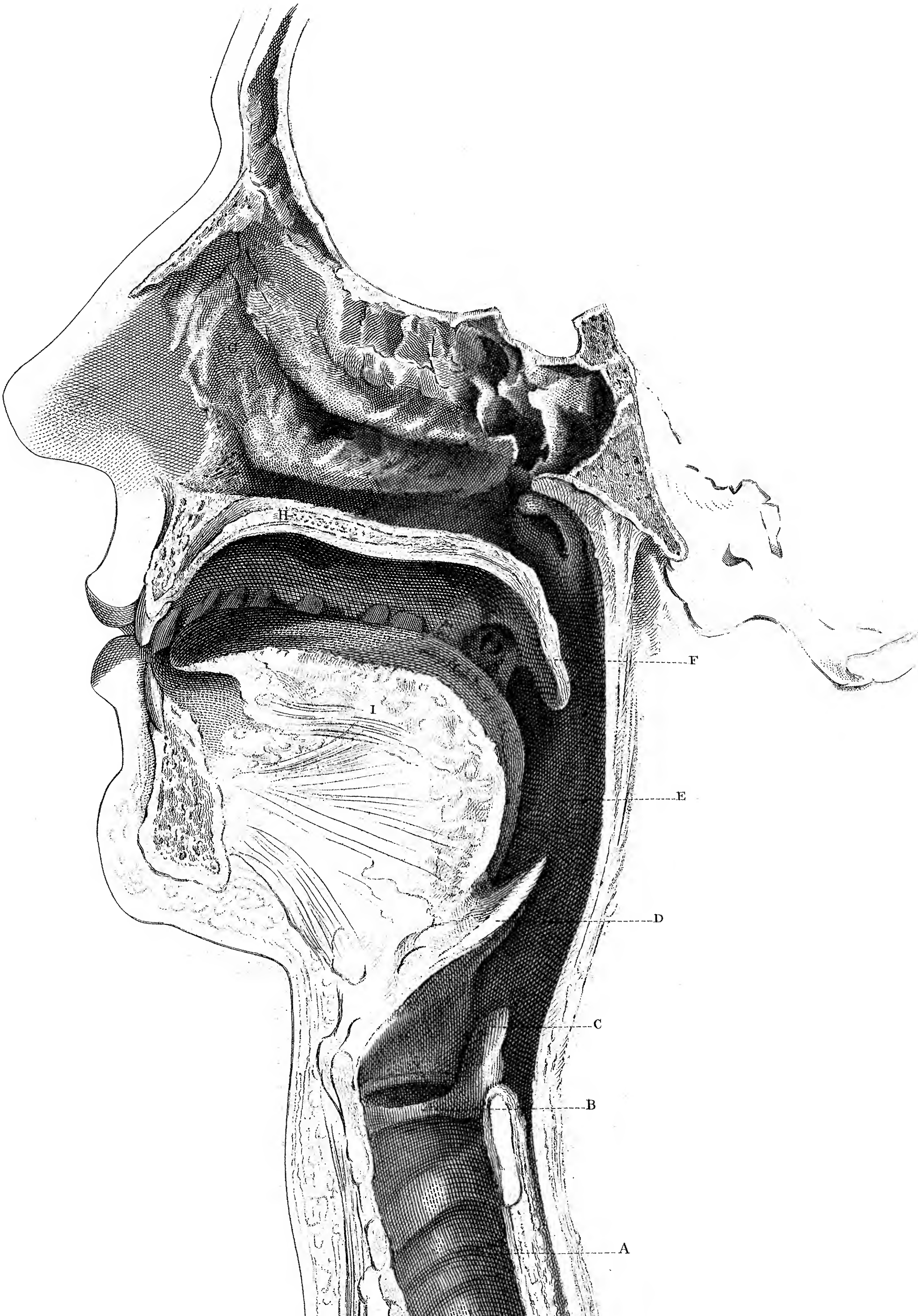
Struck with the perfection of the human voice, its precision, expression, and variety excelling the finest instruments mathematically constructed, we have more to admire in the production of those conventional sounds which become the instruments of thought and the source of all we know. Articulation results from a still more complex action of the organs of voice. In speaking, the voice is much influenced by the modulation or varying forms of the open passages, before it is articulated in the mouth; whilst with each motion of the tongue or lips there is a correspondence in the action of the velum and pharynx: so that the compression of the thorax, the adjustment of the larynx and glottis, the motions of the tongue and lips, and the actions of the pharynx and palate, must all consent before a word be uttered!

There is one part of the subject which I have omitted in the body of the paper. In speaking, the play of the chest is not the same as in the common act of breathing: the diaphragm is used less, and the ribs a great deal more. A man, preparing to speak, elevates his chest, whilst the abdomen is drawn flatter; the effect of which is to give more play to the elastic cartilages of the ribs, and the falling of the elevated chest is easy and unembarrassed; whereas, to expel the breath beyond a certain degree, requires the action of the muscles of expiration, and makes the act of speaking still more complicated.

When we think of the number of parts which must combine in office to produce the simplest articulate sound, we see the necessity for a corresponding intricacy of nervous connexions, and are less surprised to find the voice defective through derangement of the nervous system. In a person who stutters, the imperfection is obviously in the power of combination, not in the defect of any single part. Whilst he cannot combine the murmur from the glottis with the action of the pharynx, he can speak in a whisper; that is, he can articulate the faint sound of aspiration, whilst he cannot at the same time vocalize the breath. So he can sing his words without hesitation, or impediment, or spasm; because, in singing, the adjustment of the glottis and the due propulsion of the

breath by the elevated chest, are accomplished and continue uninterruptedly. Neither does he experience any distress in pronouncing the vowels and liquid consonants, for the same reason: and if he study to commence his speech with a vowel sound, he can generally add to the vibration already begun, the proper action of the pharynx. Another necessary combination distresses a person who stutters, I mean the actions of the expiratory muscles and those of the throat. He expels the breath so much in his attempt at utterance, that to produce a sound at all, the ribs must be forcibly compressed. To remove this necessity, if he be made to fill his lungs and elevate the shoulders, the elasticity of the compages of the chest will come into play so as to expel the breath without effort, and he will speak with comparative facility and comfort. Accordingly, to commence speaking with the chest fully inflated, to pitch the voice properly, to keep a measured time in speaking, and to raise the voice on a liquid letter or vowel, are some of the common means recommended for the cure of stuttering; and they are certainly those which tend to overcome the difficulty in combining the organs of speech when the defect arises from no disorder or malformation of these organs taken separately.

I have only further to hope that, by the interest which this subject is capable of exciting, I may be indulged in a subsequent attempt to unravel the nerves of the neck and throat.



Sir Charles Bell, del. J. Basire, sc.

Fig. 2.

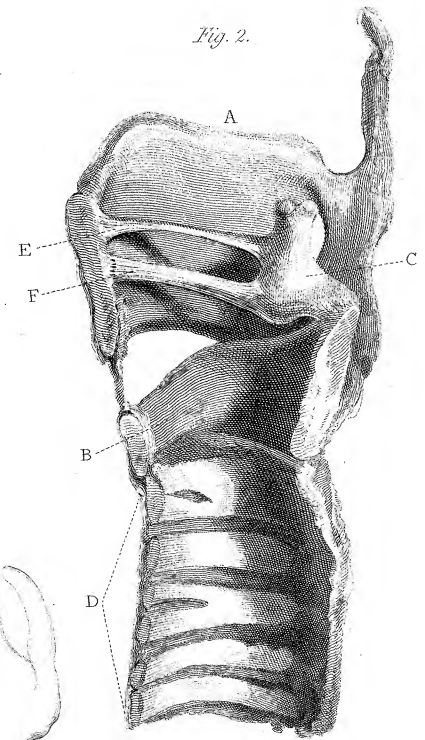


Fig. 1.

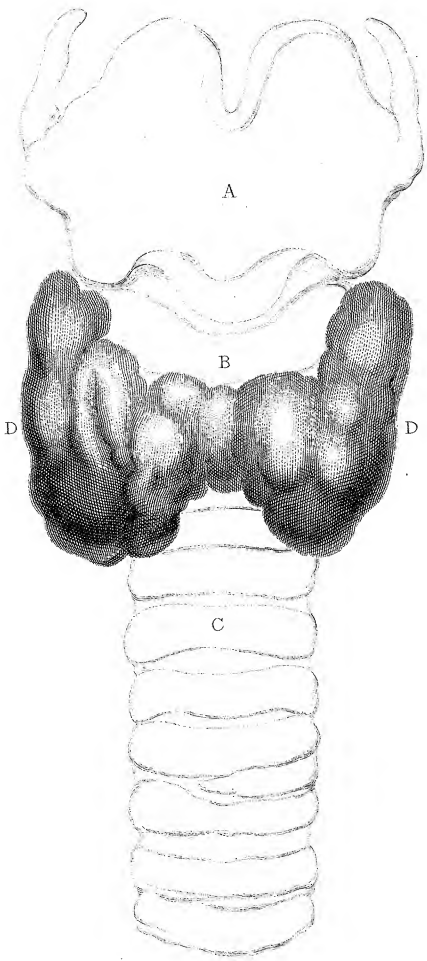
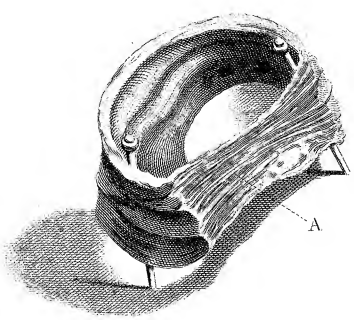


Fig. 3.



Sir Charles Bell. del.

J. Basire. sc.

Explanation of the Plates.

Plate IX.

This figure represents a section of the face and throat, exhibiting the organs of the voice in one view.

A. The trachea.

B. The chorda vocalis of the right side: above it we see the sacculus laryngis.

C. The arytenoid cartilage, which being moved by many muscles, changes the condition of the ligament or chorda vocalis.

D. The epiglottis, which falls like a valve over the glottis, as the morsel passes in swallowing, but which is important to the voice as directing the stream of vibrating air upon the fauces.

E. The bag of the pharynx, that cavity into which the sound is directed, and by the contraction of which an appulse is given in articulating certain consonants.

F. The uvula and velum palati, which, acting like a valve, and closing the passage upwards into the cavities of the face, throw the force of the contracting pharynx forwards into the mouth.

G. The cells of the bones of the face, through which some sounds are produced by reverberation.

H. The palate, the roof of the mouth, and floor of the nasal cavities.

I. The tongue.

All the dark or shaded part of the figure marks the extent of the cavities employed in the formation of the voice.

Plate X.

Fig. 1. The larynx and trachea seen in front—in outline. The thyroid gland is shaded.

A. The thyroid cartilage.

B. The cricoid cartilage.

C. The trachea.

D D. The thyroid gland seated below the larynx and embracing the upper part of the trachea.

Fig. 2. Represents a section of the larynx and part of the trachea.

A. The thyroid cartilage.

B. The cricoid cartilage.

C. The arytenoid cartilage: on the top of it we see the surface for the articulation of the appendix.

D. The cartilaginous rings of the trachea.

E. The superior thyro-arytenoid ligament extending from the thyroid to the arytenoid cartilage.

F. The lower thyro-arytenoid ligament or chorda vocalis. Between these ligaments is formed the sacculus laryngis.

We perceive how the numerous muscles attached to the arytenoid cartilage, eight in number, must affect the ligament and alter the chink of the glottis.

Fig. 3. A portion of the trachea cut out to show the transverse muscle.

A. The transverse muscle.